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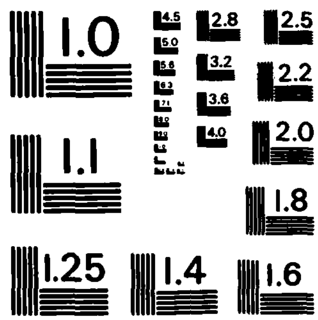

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AFGL-TR-84-0228

THE DESIGN OF AN ION/NEUTRAL MASS SPECTROMETER TO BE USED IN THE SHUTTLE ENVIRONMENT

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AIR FORCE GEOPHYSICS LABORATORIES
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

This technical report has been reviewed and is approved for publication.

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ELECTRONIC ASSEMBLIES FOR QUADRUPOLE MASS SPECTROMETER

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report discussed the development of instrumentation to be flown on the space shuttle.

The instrument is a quadrapole mass spectrometer designed to measure pre selected masses in the 1 AMU to 70 AMU region. A discussion of the various circuits will be included in this report along with a full set of schematics, drawings, wiring lists and sample control program.

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LIST OF DRAWINGS

I. INTRODUCTION

The objective of this contract is to Design and Fabricate a Quadrupole Mass Spectrometer to be used for studying the contaminants in the orbital shuttle environment.

In addition to sampling masses in the 1 AMU to 70 AMU range the instrument will attempt to measure vehicle to plasma potential and bias the quadrupole in such a way as to cancel the effects of the spacecraft charging.

The instrument will also have an ionization source to provide for neutral particle measurements.

A portable console will be fabricated to be used during vacuum and environmental testing and will provide telemetry power and monitor functions normally provided by the spacecraft during flight.

II INSTRUMENT DESCRIPTION

The electronics portion of this mass spectrometer consists of the following subassemblies:

1. DC Sweep Generator
2. DC Sweep and Bias Amplifier
3. RF Oscillator
4. Multiplier Logarithmic Electrometer
5. Auxilliary Circuits
   1a. Two Power Converters
   2a. Emission Regulator
   3a. Aperture Logarithmic Electrometer
   4a. Ground Reference Logic
   5a. High Voltage Interface
6. Test Console

2.1 DC Sweep Generator

The DC Sweep Generator shown in Drawing C-3093 produces the waveform which is used to control rod bias in both dynamic and static modes. A static mode being one which is entirely devoted to one particular mass.

The waveform is generated as counter U5 scans the proms at a rate of 10 milliseconds per step. The proms have been preprogrammed and sequentially outputs a ten bit code to the digital-to-analog converter.

Each mode may have 2^6 or 64 different analog levels as determined by addresses A0 to A5 on proms U6 and U9.

If it is desirous to sit on one mass for the entire mode, then each of the 64 words in that mode will contain the same output codes.

The microcontroller in the ground reference logic (D-4002) may select one of 32 possible scan formats. These formats are selected by way of A6 to A10 on the memory chips U6 and U9. The microcontroller has a feedback line from counter U5(C3093) which will change logic level whenever the scan counter, counts from its final output (63) back to the first output (00).

There are six extra bits available from U9. One of these bits is used to control a total ions mode, (bit D2 of U9). Another of these bits is used to control the retard bias mode (bit D1 of U9).

The output from D/A circuit U7 and U11 is used to drive the DC Sweep Amplifier and the RF oscillator (Drawing C-3092).

2.2 DC Sweep And Bias Amplifier

The DC Sweep Amplifier supplies equal but opposite polarity voltages to the quadrupole rods. The voltage amplitude depends on the particular mass to be focussed and must be maintained at a fixed ratio relative to the peak RF amplitude in order to obtain good mass resolution.

The amplifiers, U5 and U6, shown in Drawing C-3092, are a hybrid high voltage operational amplifier manufactured by Burr Brown (Model 3582J). The circuit is a linear amplifier capable of sweeping from 0 to ± 80 volts relative to the rod bias of -15 volts or +2 volts with respect to vehicle potential.

The pre-amps, U2 and U3, are a low drift version of the 741 type op amp (Burr Brown Model 3510). An op amp U2 is used to drive the main amplifier (U5 and U6). Op amp U3 controls the output amplitude of the RF oscillator.

Output of the DC sweep is supplied to telemetry in a 0 to 5 volt level by way of op amp U7 (Drawing C-3092). The output of U7 is isolated from signal ground through isolation amp U12 (Drawing C-3093).

Analog Switch U1 is a dual TTL input analog switch made by Siliconix (type DG200). In the total ions mode, the switch disconnects the sweep generator from the DC sweep amplifier. When it is desired to retard the bias, the switch puts a -15V input in amplifier U4 (Burr Brown 3581). The output of this amplifier is used as the voltage reference for the aperture electrometer. It is also used by the DC sweep amplifier to adjust for the changes in bias.

2.3 RF Oscillator

The RF oscillator (Drawing C-857) consists of two sections, the oscillator proper, and the control and monitor section.

The oscillator is a tuned secondary, Hartley oscillator with the frequency being determined by the inductance of the secondary winding and the rod capacitance. The secondary is split and capacitively coupled so that a $\pm$ DC voltage can also be applied to the rods.

The amplitude and power to the oscillator is controlled by the base drive of transistors Q1 and Q2. A servo loop consisting of amplifiers U1, U2 and U3 maintain the peak RF amplitude at a fixed ratio relative to the DC. The output of a control winding is peak detected by U3 and summed into the input of U1 which in turn supplies the base drive of transistors Q1 and Q2. Ferrite beads are used in the oscillator base drive windings and in the control winding to suppress parasitic oscillations. The predominant parasitic is usually about twenty mega hertz for this particular layout.

The oscillator coil is wound on a one inch diameter hollow cylinder of Aluminum oxide and has a turns ratio of 1,2,2,1 in the primary and a 104 turn center tap secondary.

The frequency of oscillation is fixed at about 3.5 mega-hertz and the amplitude varies from 0 to 600 volts peak to peak. The oscillator coil is mounted in a shielded cavity and isolated from the rest of the circuits to minimize RF interference.

2.4 Multiplier Logarithmic Electrometer

The schematic for the multiplier logarithmic electrometer used to measure the spectra data, is shown on Drawing C-3088. The amplifier has a logarithmic transfer characteristic and provides an output voltage of zero to five volts for an input current of 500 picoamps to 5 microamps.

The amplifier is designed around a very high input impedance (10^{15} ohms) integrated operational amplifier. This design uses the Analog Devices AD515K amplifier and is designated U1 on Drawing C-3088.

The logarithmic characteristic is obtained from the relationship between the collector current and the emmitter-base voltage of standard junction transistors.

The base emmitter voltage changes approximately 60 millivolts for every decade change of input current at 25°C. The 60 millivolts is amplified by use

of a β network consisting of R2, R4 and S1 so that the output presented to telemetry is 1 volt per decade.

The transistor Q1 is a dual NPN in the same TO-5 can. A dual transistor is used to compensate for the change in the base emmitter voltage with temperature. The compensation is accomplished by holding the collector current in the transistor on the right hand side at a constant value. The change in Vbe with temperature is approximately 2 millivolts per degree centigrade. If the right hand side tracks the left hand side, a $\frac{\Delta V}{\Delta T}$ change will appear at the common emmitter point and not at the output.

To prevent latch-up from opposite polarity inputs (spikes, transients, etc.) the amplifier has a reverse polarity limiter. Transistor Q3 will conduct and prevent the amplifier from going into an "open loop" state in the event of a positive input current.

The electrometer has a buffer amplifier to provide a TM compatible output and provide isolation from long lines.

2.5 Auxiliary Circuits

The auxiliary or support circuits are:

(a) Power Converters (2)
(b) Emission Regulator
(c) Aperture Electrometer
(d) Ground Reference Logic
(e) High Voltage Interface

2.5.1 Power Converters

There are two similar power converters shown on Drawings C-3091 and C-3090. Converter C-3090 provides the power for telemetry buffers the microcomputer and the bias amplifiers. Converter C-3091 supplies the power for all of the floating assembly including the RF oscillator.

The converters use a transformer designed around a ferrite core and driven by a fixed frequency oscillator. A buffer U3 is necessary between the oscillator U1 (C-3090) and the FET drivers Q1 and Q2 because of the input capacitance C_{gs}.

Without the buffer, the transistors Q1 and Q2 have a tendency to heat up because of the slower turn on/turn off times. A switching regulator designed with U7 and U2 increases the overall efficiency over the input voltage variation of +26 volts +32 volts.

One winding on the main power converter supplies power and synchronization to the floating converter and insulation to withstand 3000 volts was required to isolate it from the rest of the transformer.

2.5.2 Emission Regulator

The Emission Regulator circuit, Drawing C-4003, is designed to regulate anode current and bias the filament and grids to their specified voltage. A switching regulator is used in the pre regulator circuit. This pre regulator is designed around National's LH1605 Hybrid Switching Regulator. The output supplies the voltage into T1 of the emission regulator power converter.

The converter supplies power to the Filament of the emission regulator. The transformer used in the converter is designed around a ferrite core and driven by the oscillator on the main power converter. This is done to keep the two DC to DC converters, synchronous.

Anode current is monitored by operational amplifier U4 and U6. Amplifier U4 is wired in a current to voltage converter configuration and feeds optical isolator U5. This optical isolator feeds back to the pre regulator to adjust the pre regulator voltage in a way that the anode current remains constant. Amplifier U6 amplifies the voltage across current resistor R20. This signal is conditioned to a 0 to 5V level and sent to TM.

Two other parameters that are monitored and sent to TM are emitted current and filament bias. Emitted current is conditioned and amplified by two operational amplifiers contained in U7. Filament bias is monitored by U3.

The emission regulator is enabled by the signal Mode II, from the ground reference logic. This signal is isolated from power return through optical isolator U8 (GE MCA255).

2.5.3 Aperture Logarithmic Electrometer

The aperture electrometer is used to measure ion particle densities and neutral pressure. This information will be used to correlate with the spectra output data.

The operation of the aperture electrometer (Drawing C-3089) is similar to the previously mentioned multiplier electrometer. One change is in the logging transistor type used. Another is the reverse polarity limiter.

To prevent latch-up from opposite polarity spikes, diode CR3 will conduct and prevent the amplifier from going into an open loop state in the event of a negative input current.

2.5.4 Ground Reference Logic

The ground reference logic is designed around an eight bit integrated microcomputer which is

a generic product of the Motorola 6800 micro-processor family.

The 68705 (U3 of D-4002) has three digital I/O ports and one analog multiplexed port.

The three digital ports are assigned to:

(1) Accept commands during testing and flight.
(2) Select a sweep mode by controlling the memory in the DC sweep generator circuit.
(3) Set the spectrometer bias level by way of U8, U12 and U13 on D-4002.

The digital ports are programmed to be either input or output during a cold start initialization. The commands are inputed to the micro-computer on Pins 9, 10 and 11 with a command of 111 serving as a reset in case of computer hang up.

After a command has been accepted from the spacecraft, the microcomputer will refer to a look up table which has been burned into its monitor ROM and proceed to execute that particular subroutine.

The commands are latched until a new command is sent which eliminates the need for handshaking and allows for a simple polling subroutine to detect a change in the command word status.

Pins 25 to 29 are programmed to be outputs and control the floating memory bank, by way of opto isolators U1, U2 and U3 on C-3093.

This output could be considered a page register with each page containing a different quadrupole rod sweep mode.

Pins 33 to 39 are used to generate the spectrometer bias. The spectrometer bias is generated by applying a digital word to U8 which sets an analog level between 0 and +10 volts. The D/A output is then amplified by way of U16, U15 for the lower voltage mode or by way of U17 and the Venus High Voltage Supply for the high voltage mode.

The low voltage mode has two parts: A 0 to 10 volt sweep and a +10 volt to +100 volt sweep. The high voltage sweep is used for the region of +100 volts to +2000 volts.

Two analog switches are used to change the gain and offset of the amplifiers and are controlled by digital bits A5 and A6.

A high voltage relay K6 of D-4002 is used to output the bias voltage to the floating section. The relay is rated for 8000 volts and is manufactured by the Kilovac Corporation. The relay position is controlled by a bit A6 from the microcomputer.

The microcomputer uses one port for interfacing with analog voltages. A built in multiplexer and A/D converter allow for several analog voltages.

2.5.5 High Voltage Interface

The high voltage interface between the floating spectrometer and the spacecraft ground reference, includes power, digital and analog signals.

The power interface is a transformer winding which is insulated to withstand greater than 3000 volts of stress. The digital interface is Darlington Opto Isolators such as the Hewlett Packard HP2730 which require relatively low input currents, and are driven from the buffered output port of the microcomputer.

The analog signals coming back from the floating spectrometer are the aperture electrometer the DC monitor and the RF monitor.

The isolation amplifier used for the analog signals, is an Analog Device AD294. The amplifier fits into the standard 40 pin package profile and is rated for 4000 volts.

The amplifier uses the chopper transformer method of isolation to couple signals back to telemetry ground referenced circuits.

New opto isolated analog integrated circuits are available but none have a high voltage specification good enough to be used in this instrument.

2.6 Test Console

A test console is supplied with the mass spectrometer experiment to allow for field test without the need of a large number of test instruments.

The test console will supply the power and timing functions and display mode and data signals received from the experiment.

Auxiliary jacks are available to allow for more precise measurements of each parameter.

VPMS
C-211

P1	Spectra Log Elect.	DEM-9S
1	+15V	TP2
2	-15V	TP4
3		
4	Multiplier Elect. Monitor out	J3-45; J10-10; P23-6
5		
6		
7		
8		
9	Signal RTN $\frac{1}{=}$	TP7

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J2	Main Power Converter		C-4010	2DA31S
1	+30V	J4-1		
2	+15V	TP2		
3	+5V	TP3		
4	-15V	TP4		
5	-90V	J4-5		
6	-125V	J3-12		
7				
8	+125V	J3-10		
9				
10	+28V H.V. Supply	J10-44		
11	+28V Supply	LF1-2		
12	+28V Supply	LF1-2		
13				
14				
15				
16				
17				
18				
19				
20	PS Pre Reg	J4-16		
21	+28V H.V. RTN	VEN3		
22	Pwr RTN	TP5		
23	PWR RTN	TP5		
24	Signal RTN	TP7		
25	Signal RTN	TP7		
26	Temperature Monitor	J3-41		
27				
28				
29				
30	SYNC A	J4-51		
31	SYNC B	J4-52		

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J3	Ground Reference Logic		C-4012 2DB52P
1	HV Bias Monitor Out		J10-11; P23-5
2	HV Control Signal		VEN 2
3	HV Output - Low Range		HVR-5
4	HV Relay - Control		HVR-2
5	HV CMD Out		J4-8
6			
7	+28V HV Bias Supply - In		J10-46
8	+28V HV Bias Supply - Out		VEN-1
9			
10	+125V	J2-8	
11			
12	-125V	J2-6	
13			
14	-15V	TP4	
15	+5V	TP3	
16	+15V	TP2	
17			
18			
19			
20	EXT Clock	J10-51	
21	Sweep Clock	J7-20	
22	End of Mass Scan	J7-21	
23	Mode II Select	J4-28	
24	CMD Reset	J10-5	
25			
26	HV Bias Off	J10-7	

J3	Ground Reference Logic	Page 2
27	HV Bias On	J10-6
28	CMD D	J4-8; J10-20
29	CMD C	J10-19
30	CMD B	J10-4
31	CMD A	J10-3
32	CMD RTN	TP6
33	CMD RTN	TP6
34	Signal RTN	TP7
35	Signal RTN	TP7
36		
37		
38		
39	Mult. HV Stat In	J4-26
40	Mult HV Mon In	J4-15
41	Temperature Mon In	J2-27
42	Filament Bias Mon In	J4-30
43	PS. Pre Reg Mon In	J4-32
44	MUX Mon Out	J10-8; P23-8
45	Multiplier Elect Mon In	J10-10; P1-4; P23-6
46	MUX SYNC	
47		
48	B4	J7-31
49	B3	J7-30
50	B2	J7-29
51	B1	J7-28
52	B0	J7-27

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J4	Emission Regulator 2DB52S	
1	+30V	J2-1
2	+15V	TP2
3		
4	-15V	TP4
5	-90V	J2-5
6		
7		
8	HV CMD In	J7-18
9		
10	+5V	TP3
11		
12		
13		
14	Mult HV RTN (Velonex)	
15	Mult HV Mon	J3-40
16	Pre Reg PS	J2-20
17		
18	Signal RTN	TP7
19	Signal RTN	TP7
20	Power RTN	TP5
21		
22	CMD RTN	TP6
23		
24	Mult HV On	J10-22
25	Mult HV Off	J10-23
26	Mult HV Status	J3-39

J4	Emission Regulator	Page 2
27	+28 HV Supply In	J10-45
28	Mode II Select	J3-23
29	Anode CUR Mon Out	J10-26; P23-10
30	Filament Bias Mon Out	J3-42
31	Emission Mon Out	J10-27; P23-9
32	PS Preg Mon Out	J3-43
33		
34		
35		
36	+28V Battery (Int LCK)	J10-48
37	Anode	
38	Filament	
39	Filament Bias	
40	Filament Holder	
41	F1	
42	F2	
43	F3	
44	Box	
45	Box Bottom	
46	G2	
47	G3	
48		
49		
50		
51	SYNC A	J2-30
52	SYNC B	J2-31

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J5	Sweep & Bias Amp Floating Converter C-4011	2DA31 Floating
1	DC Mon Out	J6-10
2	Total Ions	J6-9
3	Ret ARD Ions	J6-8
4	RF Control	J9-8
5	RF Sweep	J6-6
6	-40V F	J6-5
7	-15V F	J6-4
8	+5V F	J6-3
9	+15V F	J6-2
10	+28V F	J6-1
11	FPB	J14-B
12		
13	FPA	J14-A
14		
15		
16		
17	Comm Q	P8-7
18		
19	-15V F^2	P8-4
20		
21	+15V F^2	P8-3
22		
23		
24	-DC	J9-4
25		
26	+DC	J9-3
27		
28		
29		
30	Floating RTN	HVR3

J6	DC Sweep Generator 2DA31	Floating
1	+28V F	J5-10
2	+15V F	J5-9
3	+5V F	J5-8
4	-15V F	J5-7
5	-40V F	J5-6
6	RF Sweep	J5-5
7		
8	Retard Ions	J5-3
9	Total Ions	J5-2
10	DC Mon In	J5-1
11	+15V F	P8-1
12		
13	-15V F	P8-2
14		
15		
16		
17	+28V RF Supply	J9-7
18		
19	G4	
20		
21	G6	
22		
23	Floating RTN	HVR3
24		
25		
26		
27	Aperature Mon In	P8-5
28		
29	RF Mon In	J9-9
30		
31	Spare Mon In	NC

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J7	DC Sweep Generator	2DA-31P
1		
2	+15V	TP2
3	+5V	TP3
4	-15V	TP4
5		
6		
7		
8		
9		
10		
11	Signal RTN	TP7
12	Signal RTN	TP7
13	CMD RTN	TP6
14	CMD RTN	TP6
15	RF on	J10-38
16	RF off	J10-39
17	RF Stats on	J10-52
18	HV CMD	J3-5; J4-8
19		
20	Sweep Clock	J3-21
21	End of Mass Scan	J3-22
22	RF Mon out	J10-24; P23-12
23	No Mon out	J10-25; P23-11
24	Aperature Mon out	J10-13; P23-7
25	Spare Mon out	
26		
27	B0	J3-52
28	B1	J3-51
29	B2	J3-50
30	B3	J3-49
31	B4	J3-48

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P8	Grid Aperature Elect.		DEM-9S	Floating
1	+15F	J6-11		
2	-15F	J6-13		
3	+15F2	J5-21		
4	-15F2	J5-19		
5	Grid Aperature Mon out	J6-27		
6	Floating RTN	HVR-3		
7	Comm Q	J5-17		
8	+15F	J9-1		
9	-15F	J9-2		

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J9	RF Oscillator		DEM-9S	Floating
1	+15VF	P8-8		
2	-15VF	P8-9		
3	+DC	J5-26		
4	-DC	J5-24		
5				
6	Floating RTN	HVR-3		
7	RF Supply	J6-17		
8	RF Control in	J5-4		
9	RF Amplitude Mon out	J6-29		

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J10	External Signals	2D-5 S	
1	+28V	LF1-1	
2	+28V	LF1-1	
3	CMD a	J3-31	
4	CMD b	J3-30	
5	CMD Reset	J3-24	
6	HV Bias on	J3-27	
7	HV Bias off	J3-26	
8	Mux Mon Tm	P23-16	
9	Grid Aper Mon Tm	P23-15	
10	Multiplier Mon Tm	P23-14	
11	Vehicle Pot. Mon. Tm	P23-13	
12	Mux Mon GSE	J3-44	P23-8
13	Grid Aper Mon GSE	J7-24	P23-7
14	Multiplier Mon GSE	J3-45	P23-6
15	Vehicle Pot Mon GSE	J3-1	P23-5
16	Sig. RTN GSE	TP-7	
17			
18	PWR RTN	TP-5	
19	CMD c	J3-29	
20	CMD d (H.V. CMD)	J3-28	
21			
22	Mult HV on	J4-24	
23	Mult HV off	J4-25	
24	RF Amplitude Mon Tm	J7-22	P23-12
25	DC Amplifier Mon Tm	J7-23	P23-11

J10	External Signals		page 2	
26	Collected Current	Tm	J4-29	P23-10
27	Emitted Current	Tm	J4-31	P23-9
28	RF Amplitude Mon	GSE	P23-4	
29	DC Amplifier Mon	GSE	P23-3	
30	Collected Current	GSE	P23-2	
31	Emitted Current	GSE	P23-1	
32	Sig. RTN	GSE	TP-7	
33				
34	PWR RTN		TP-5	
35	CMD RTN		TP-6	
36	CMD RTN		TP-6	
37				
38	RF on		J7-15	
39	RF off		J7-16	
40	Sig. RTN	Tm	TP-7	
41	Sig. RTN	Tm	TP-7	
42				
43				
44	HV +28V Supply out		J2-10	
45	Multiplier +28V Supply in		J4-27	
46	HV Bias +28V Supply in		J3-7	
47	ER +28V Supply out		LF1-2	
48	ER +28V Supply in		J4-36	
49	RF Interlock out		J7-9	
50	RF Interlock in		J7-10	
51	Ext Clk GSE		J3-20	
52	RF Status GSE		J7-17	

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P10	External Signals	2D52P
1	+28V	J13-1
2	+28V	J13-2
3	CMD a	J13-3
4	CMD b	J13-4
5	CMD RESET	J13-7
6	HV Bias on	J13-11
7	HV Bias off	J13-23
8	Mux Mon Tm	J12-4
9	Grid Aper Mon Tm	J12-3
10	Multiplier Mon Tm	J12-2
11	Vehicle Pot Mon Tm	J12-1
12	Mux Mon GSE	J11-13
13	Grid Aper Mon GSE	J11-12
14	Multiplier Mon GSE	J11-11
15	Vehicle Pot Mon GSE	J11-10
16	Signal RTN GSE	J11-9
17		
18	PWR RTN	J13-14
19	CMD c	J13-5
20	CMD d (H.V. CMD)	J16-6
21		
22	Mult HV on	J13-12
23	Mult HV off	J13-23
24	RF Amplitude Mon Tm	J12-12
25	DC Amp Mon Tm	J12-11
26	Collected Current Tm	J12-10

P10	External Signals	page 2
27	Emitted Current Tm	J12-9
28	RF Amplitude Mon GSE	J11-25
29	DC Amplitude Mon GSE	J11-24
30	Collected Current GSE	J11-23
31	Emitted Current GSE	J11-22
32	Signal RTN GSE	J11-21
33		
34	PWR RTN	J13-15
35	CMD RTN	J13-16
36	CMD RTN	J13-17
37		
38	RF on	J13-13
39	RF off	J13-25
40	Signal RTN Tm	J12-6
41	Signal RTN Tm	J12-14
42		
43		
44	HV +28V Supply out	J11-7
45	Mult +28V Supply in	J11-6
46	HV Bias +28V Supply in	J11-19
47	E.R. +28V Supply out	J11-5
48	E.R. +28V Supply in	J11-18
49	RF Interlock out	J11-1
50	RF Interlock in	J11-14
51	Ext Clk	J11-15; J12 15
52	RF Status	

VPMS
C-211

J11	GSE & Interlocks	DBH 25
1	RF Interlock 12	P10-49
2		
3		
4		
5	Emission Reg Interlock 12	P10-47
6	HV Interlock 13	P10-45
7	HV Interlock 23	P10-44
8		
9	Signal RTN	P10-16
10	Vehicle Potential Mon	P10-15
11	Mult. Elect Mon	P10-14
12	Grid Aper Mon	P10-13
13	Mux Mon	P10-12
14	RF Interlock 22	P10-50
15	Ext Clk	J12-15; P10-51
16		
17		
18	Emission Reg Interlock 22	P10-48
19	HV Interlock 33	P10-46
20		
21	Sig RTN	P10-32
22	Ion Source Emitted Current Mon	P10-31
23	Ion Source Collected Current Mon	P10-30
24	DC Amplifier Mon	P10-29
25	RF Amplitude Mon	P10-28

VPMS
C-211

J12	Telemetry	DAH 15
1	Vehicle Potential Mon	P10-11
2	Mult Elect Mon	P10-10
3	Grid Aper Mon	P10-9
4	Mux Mon	P10-8
5		
6	Signal RTN	P10-40
7		
8		
9	Ion Source Emitted Current	P10-27
10	Ion Source Collected Current	P10-26
11	DC Amplifier Mon	P10-25
12	RF Amplitude Mon	P10-24
13		
14	Signal RTN	P10-41
15	Ext Clk	J11-15; P10-51

VPMS
C-211

J13	Power and Commands	DBH 25
1	+28V	P10-1
2	+28V	P10-2
3	CMD a	P10-3
4	CMD b	P10-4
5	CMD c	P10-19
6	CMD d	P10-20
7	CMD RESET	P10-5
8		
9		
10		
11	HV Bias on	P10-6
12	Mult HV on	P10-22
13	RF on	P10-38
14	PWR RTN	P10-18
15	PWR RTN	P10-34
16	CMD RTN	P10-35
17	CMD RTN	P10-36
18		
19		
20		
21		
22		
23	HV Bias off	P10-7
24	Mult HV off	P10-23
25	RF off	P10-39

VPMS
C-211

P14	Floating Power	JF2S
A	FPA	J5-13
B	FPB	J5-11

VPMS
C-211

P15	Vehicle Potential	JF1P1S
A	HV Bias (Floating RTN)	HVR-3
B		

OTHER COMPONENTS & CONNECTIONS

PWR TIE POINTS

TP-2	+15V
TP-3	+5V
TP-4	-15V
TP-5	PWR RTN
TP-6	CMD RTN
TP-7	Sig RTN

VELONEX

Velo-1	HV Output
Velo-2	+28V Supply
Velo-3	PWR RTN
Velo-4	HV RTN

HV RELAY

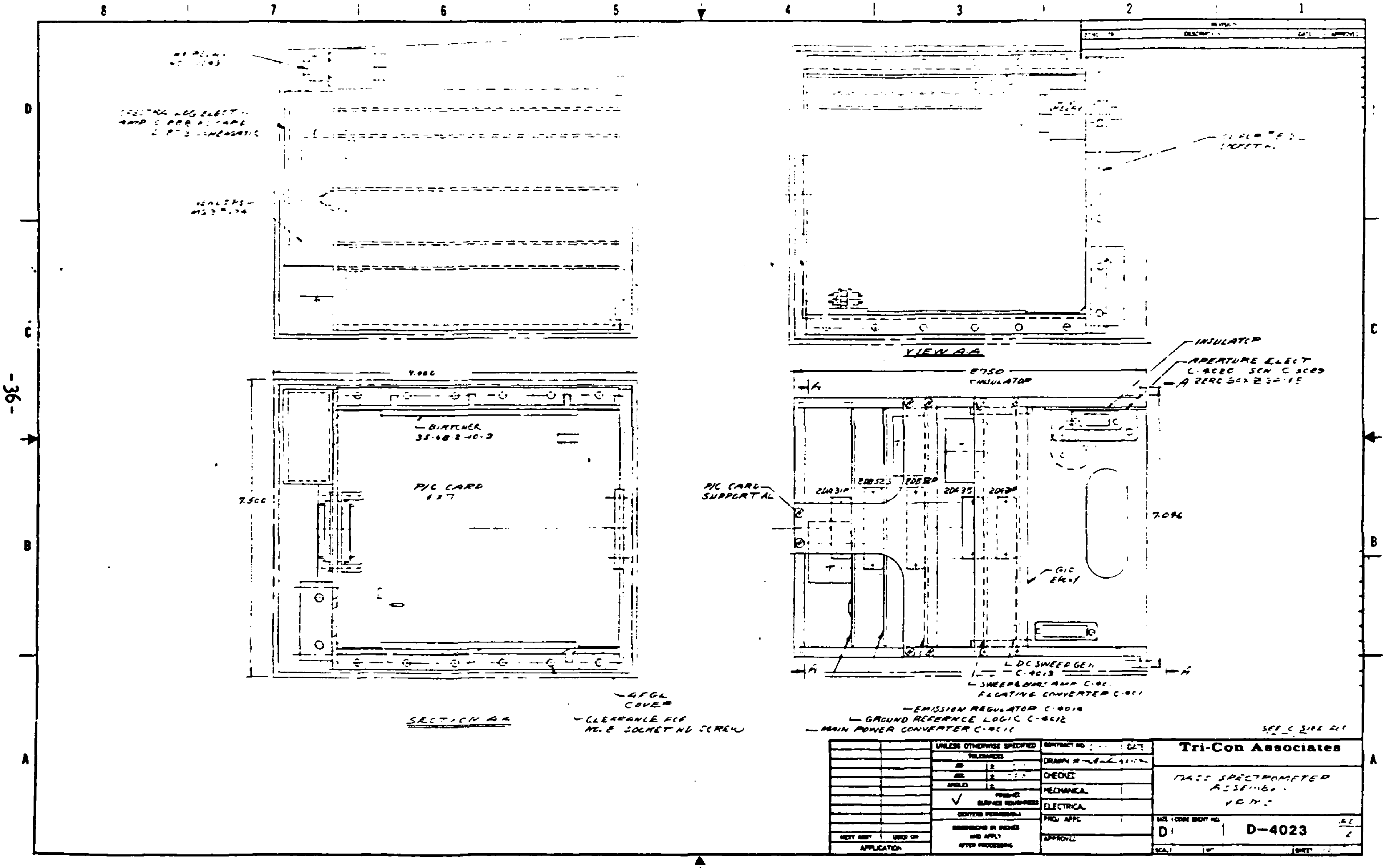
HVR-1 (+) Coil
HVR-2 (-) Coil
HVR-3 Common
HVR-4 N.O.
HVR-5 N.C.

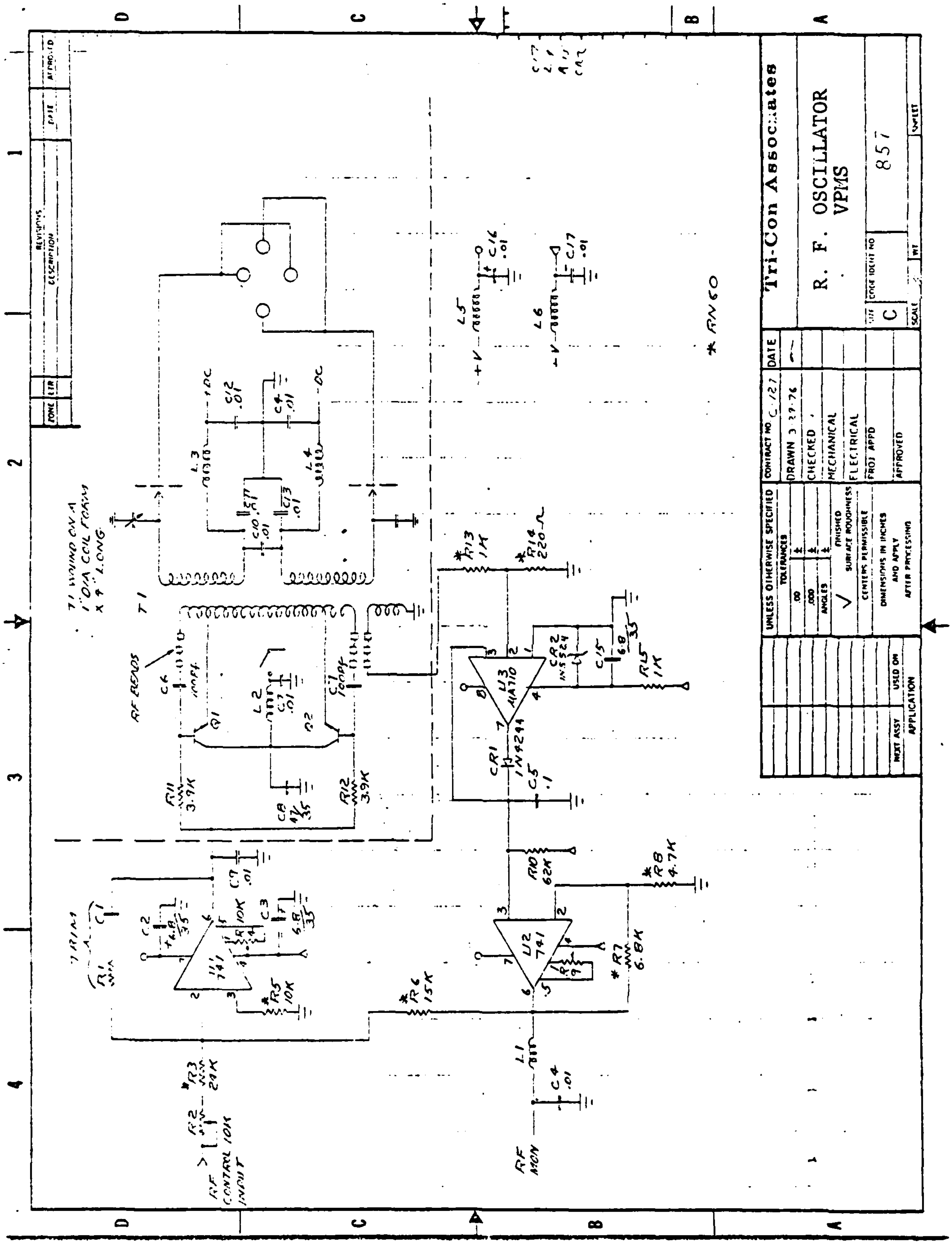
VENUS P.S.

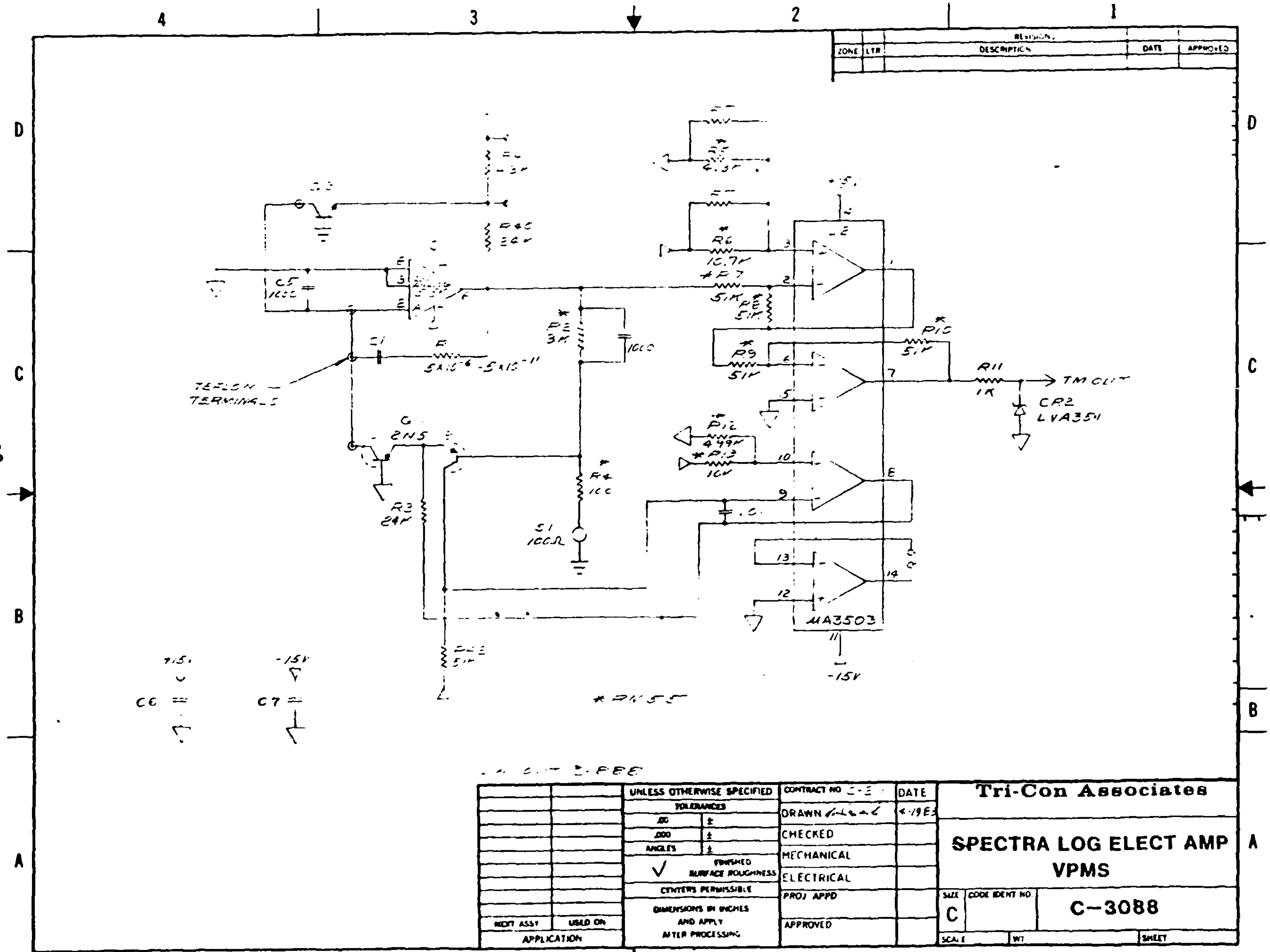
Ven-1	+28V
Ven-2	Volt Adj
Ven-3	+28V RTN
Ven-4	Chassis
Ven-5	Test out
Ven-6	HV Output

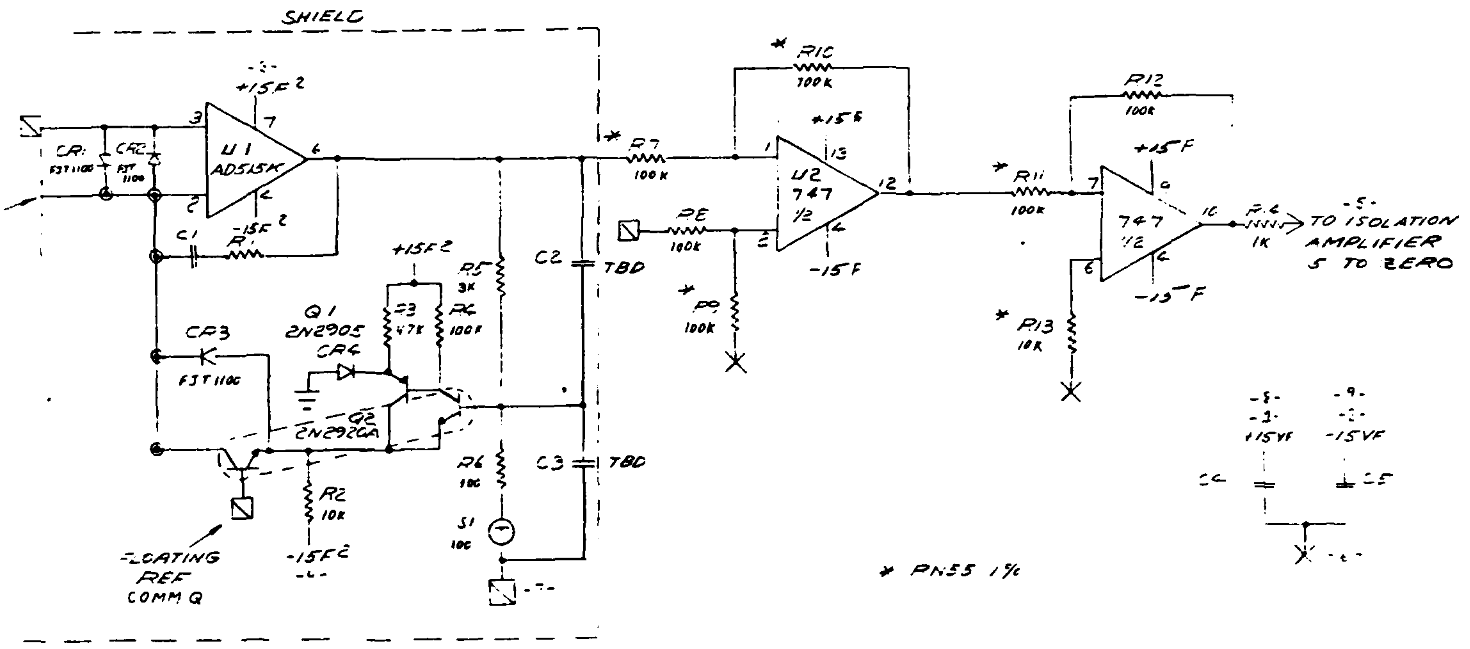
FILTERS

LF1-1	+28V Line Filter input
LF1-2	+28V Line Filter output
LF2-1	PWR RTN Line Filter input
LF2-2	PWR RTN Line Filter output


VIEW A-A
SECTION A-A
INSULATOR
APERTURE ELECT
A ZERO BOX
.750
INSULATOR
P/C CARD SUPPORT AL
7.096
G/C ELECT
DC SWEEP GEN
SWEEP & BIAS AMP
FLOATING CONVERTER
EMISSION REGULATOR C-4014
GROUND REFERENCE LOGIC C-4012
MAIN POWER CONVERTER
P/C CARD 6x7
BIRTCHER
4.000
7.500
COVER
CLEARANCE FOR NO. 8 SOCKET HD SCREW
Tri-Con Associates
MASS SPECTROMETER ASSEMBLY
D-4023
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
FINISH
SURFACE ROUGHNESS
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
CONTRACT NO.
DATE
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
PROJ. APPL.
APPROVAL
NEXT ASSY
USED ON
APPLICATION
SIZE
CODE IDENT NO.
SCALE
SHEET
REVISION
DESCRIPTION
APPROVAL


Tri-Con Associates
R. F. OSCILLATOR
VPMS
C
857
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
FINISHED
SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES
AND APPLY
AFTER PROCESSING
CONTRACT NO
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
PROJ APPD
APPROVED
NEXT ASSY
USED ON
APPLICATION
DATE
SCALE
SHEET
REVISIONS
DESCRIPTION
ZONE
LTR
DATE
APPROVED
* RN60
T1
RF BEADS
RF MON
RF CONTROL INPUT
U1 741
U2 741
U3 MA710
CR1 1N4244
L1
L2
L3
L4
L5
L6
+V
-V


Tri-Con Associates
SPECTRA LOG ELECT AMP
VPMS
C-3088
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
FINISHED SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
NEXT ASSY
USED ON
APPLICATION
CONTRACT NO
DATE
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
PROJ APPD
APPROVED
SIZE
C
CODE IDENT NO
SCALE
WT
SHEET
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
TM OUT
R11
1K
CR2
LVA351
MA3503
-15V
+15V
R6
10.7K
R9
51K
S1
100Ω
R3
24K
TEFLON TERMINALS
C5
C6
C7
-15V
+15V



LAYOUT C-4020

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
TOLERANCES
.00 ±
.000 ±
ANGLES ±
√ FINISHED SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING

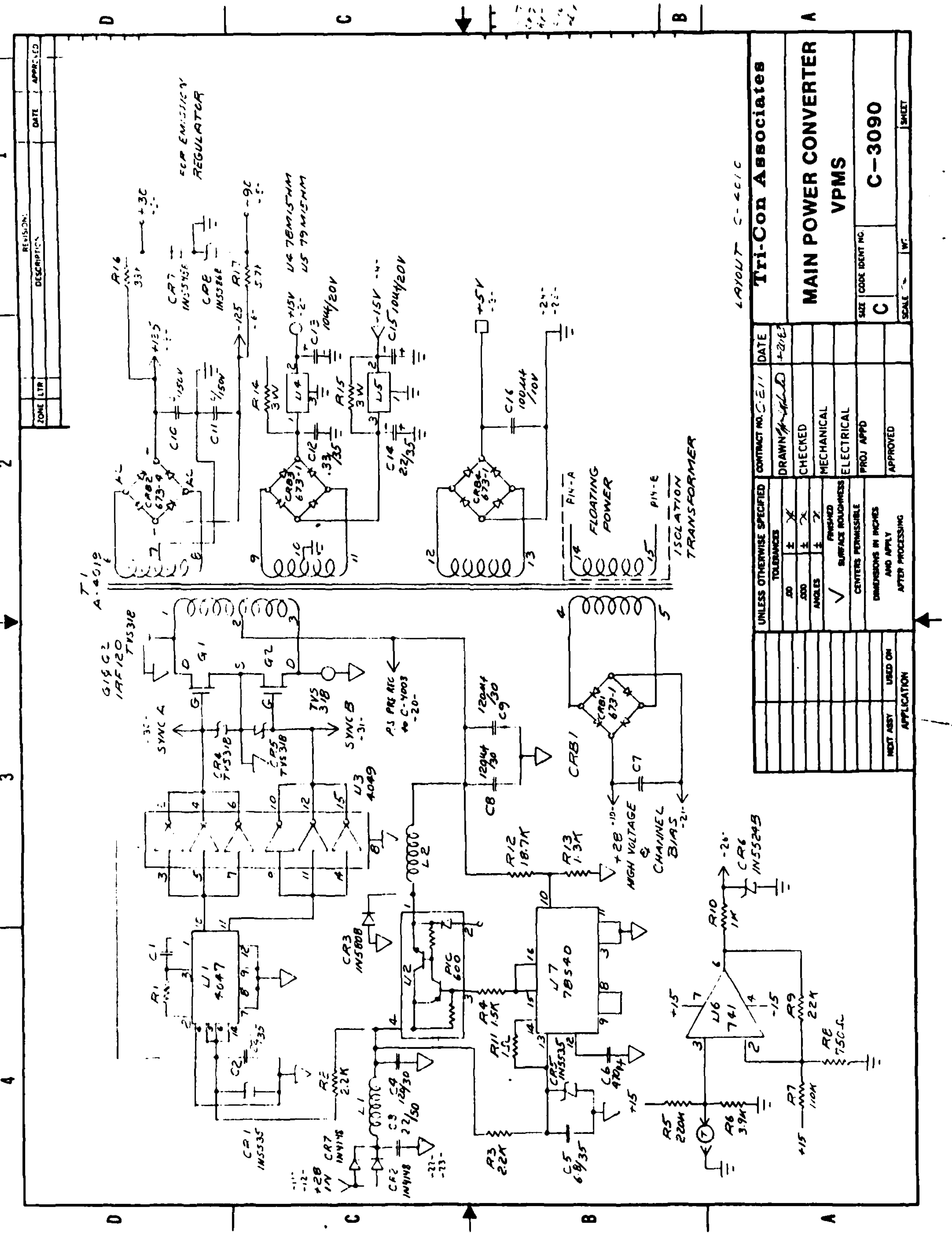
	DATE
CONTRACT NO.	
DRAWN	4-21-83
CHECKED	
MECHANICAL	
ELECTRICAL	
PROJ. APPD	
APPROVED	

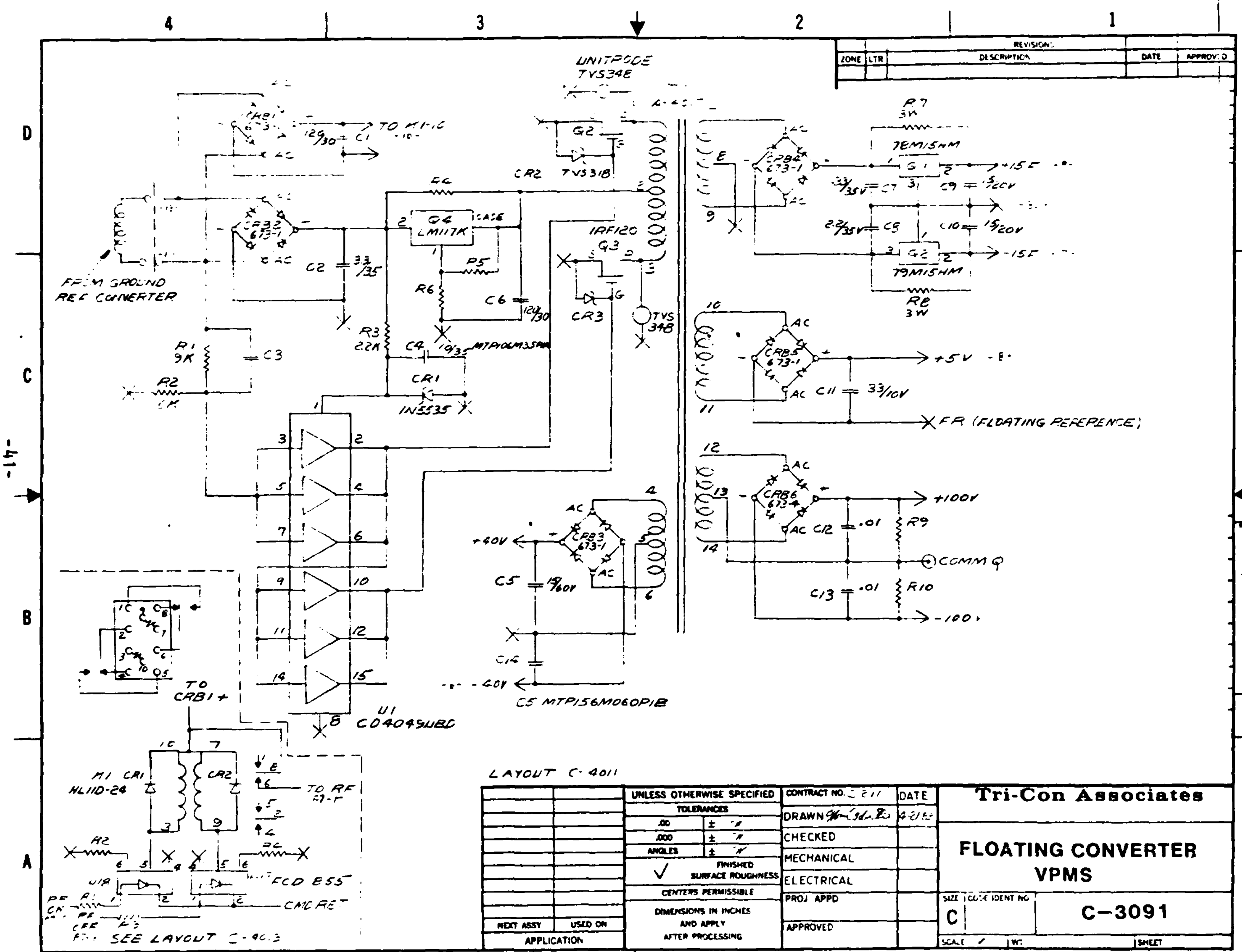
Tri-Con Associates

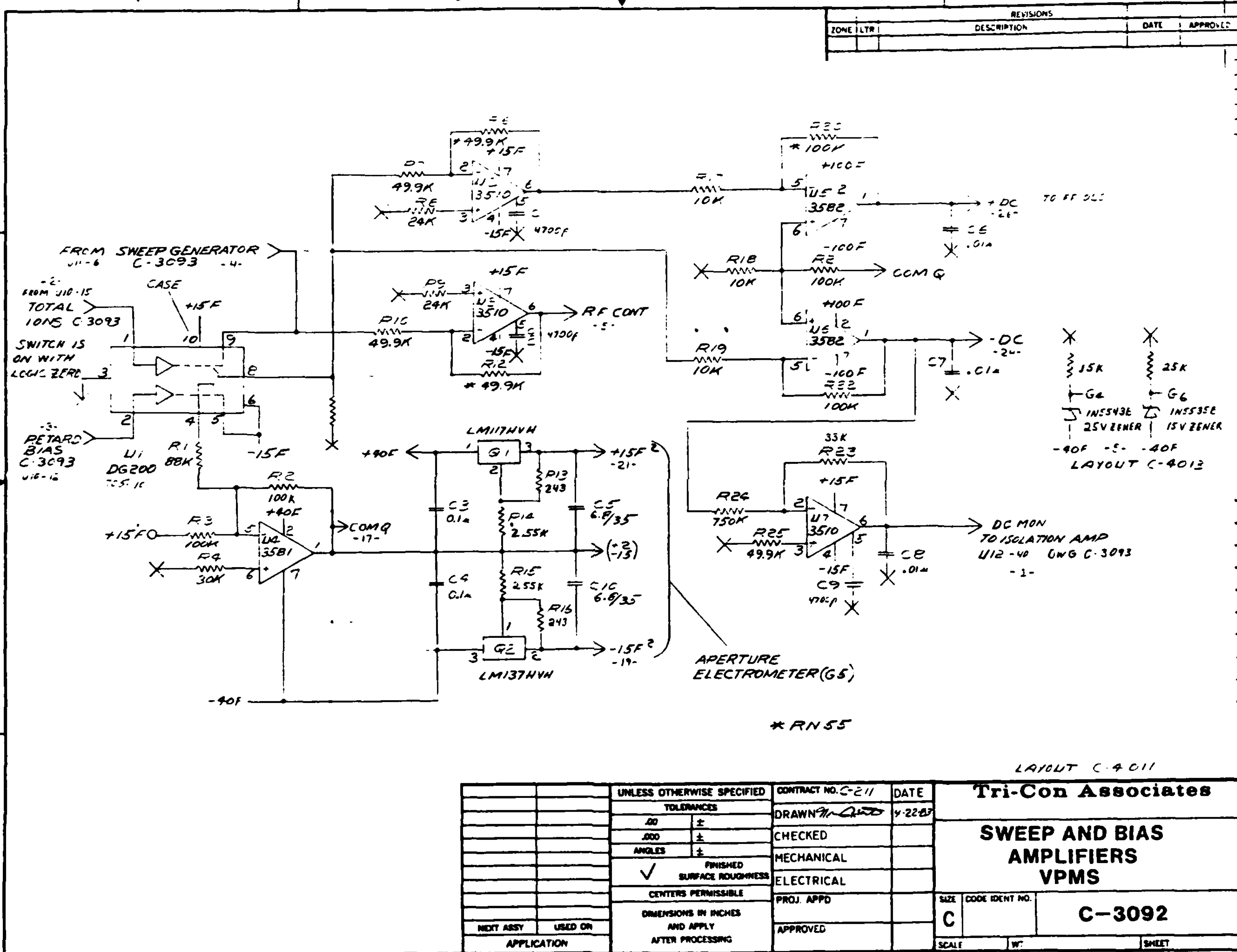
APERTURE ELECT
VPMS

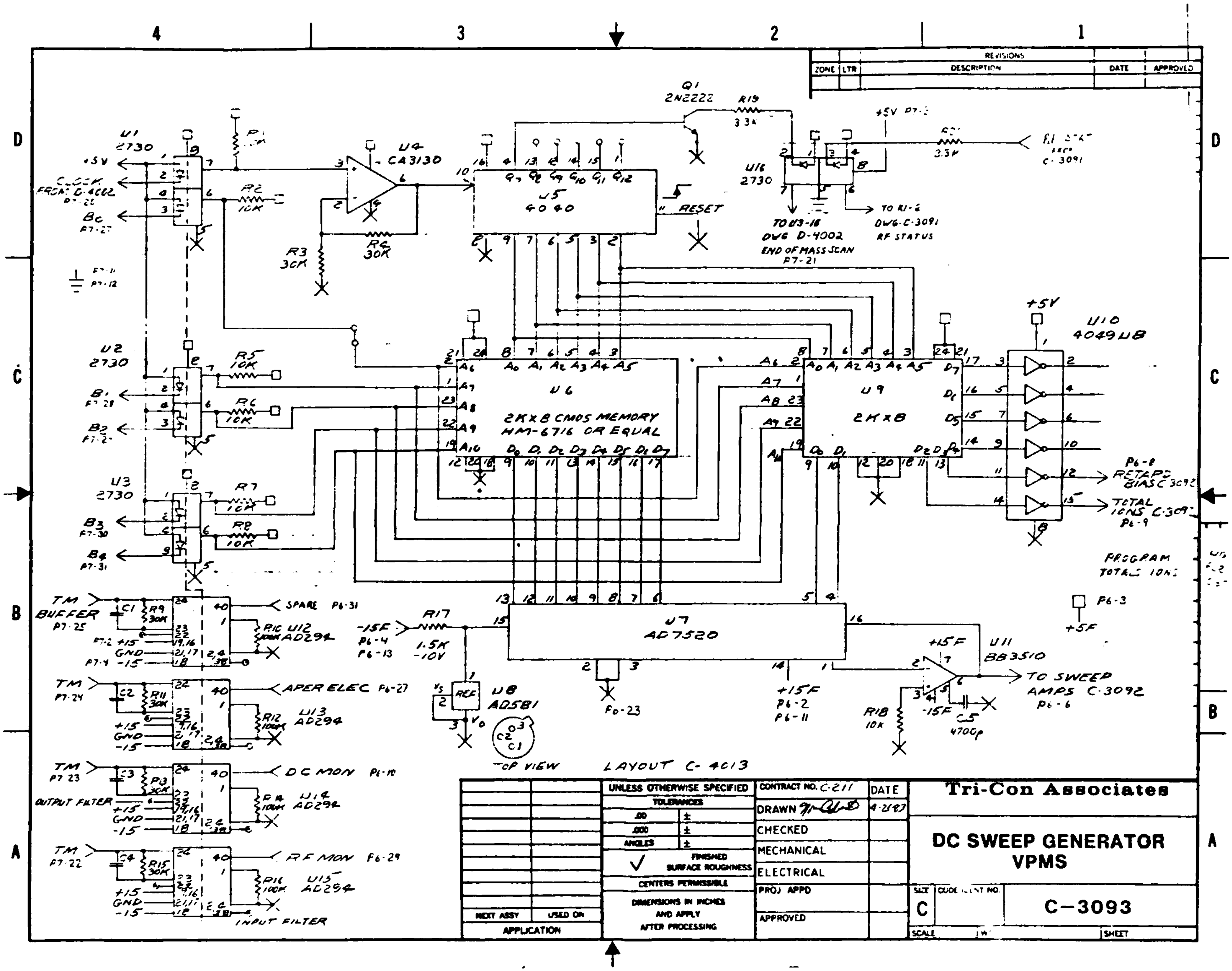
SIZE C | CODE IDENT NO | **C-3089**

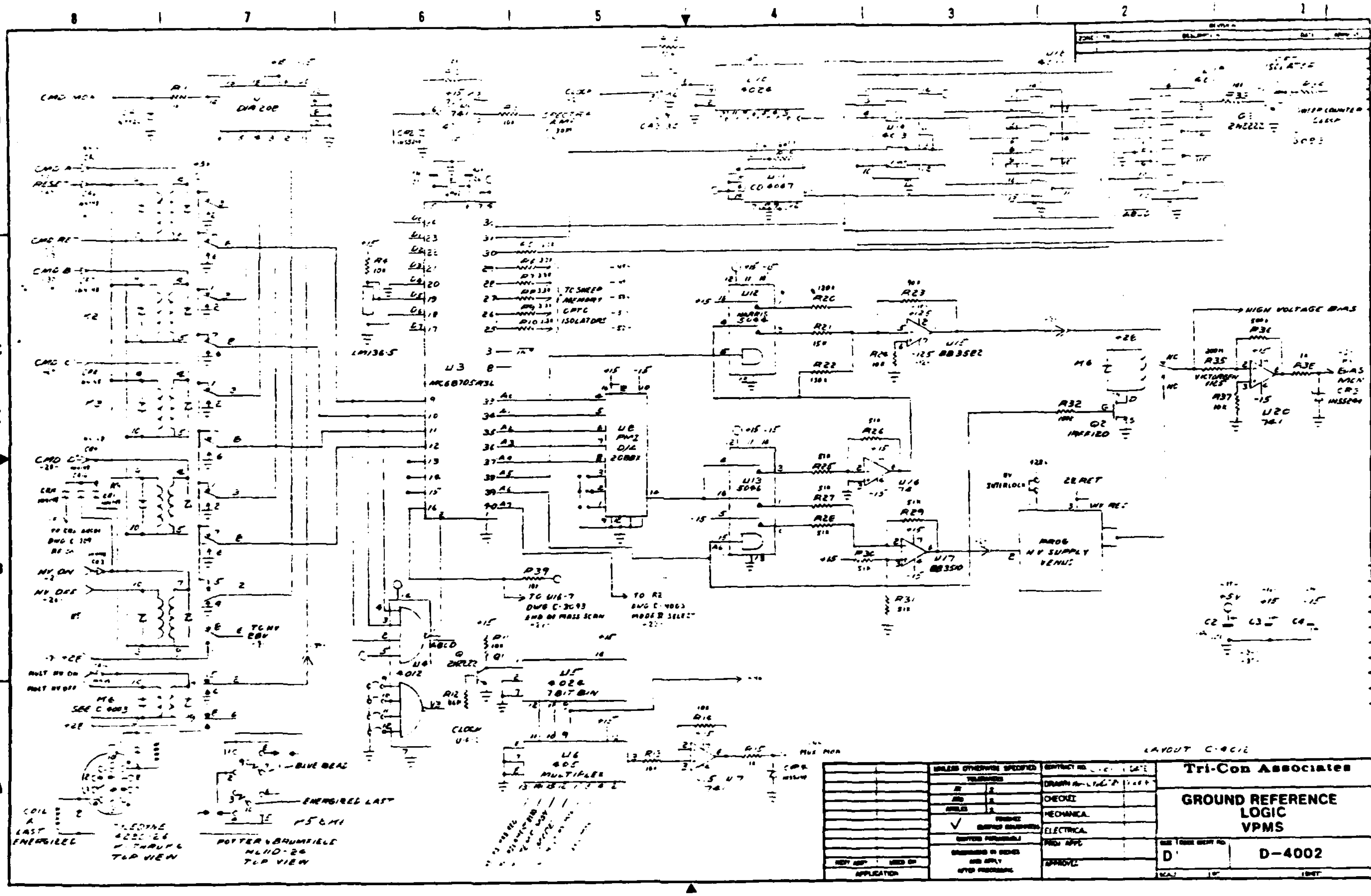
SCALE | SHEET


Tri-Con Associates
MAIN POWER CONVERTER
VPMS
C-3090
ISOLATION TRANSFORMER
FLOATING POWER
HIGH VOLTAGE & CHANNEL BIAS
LAYOUT
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
NEXT ASSY
USED ON
APPLICATION
CONTRACT NO.
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
PROJ APPD
APPROVED
DATE
SIZE
CODE IDENT NO.
SCALE
WT.
SHEET
REVISION
DESCRIPTION
ZONE
LTR
DATE
APPROVED

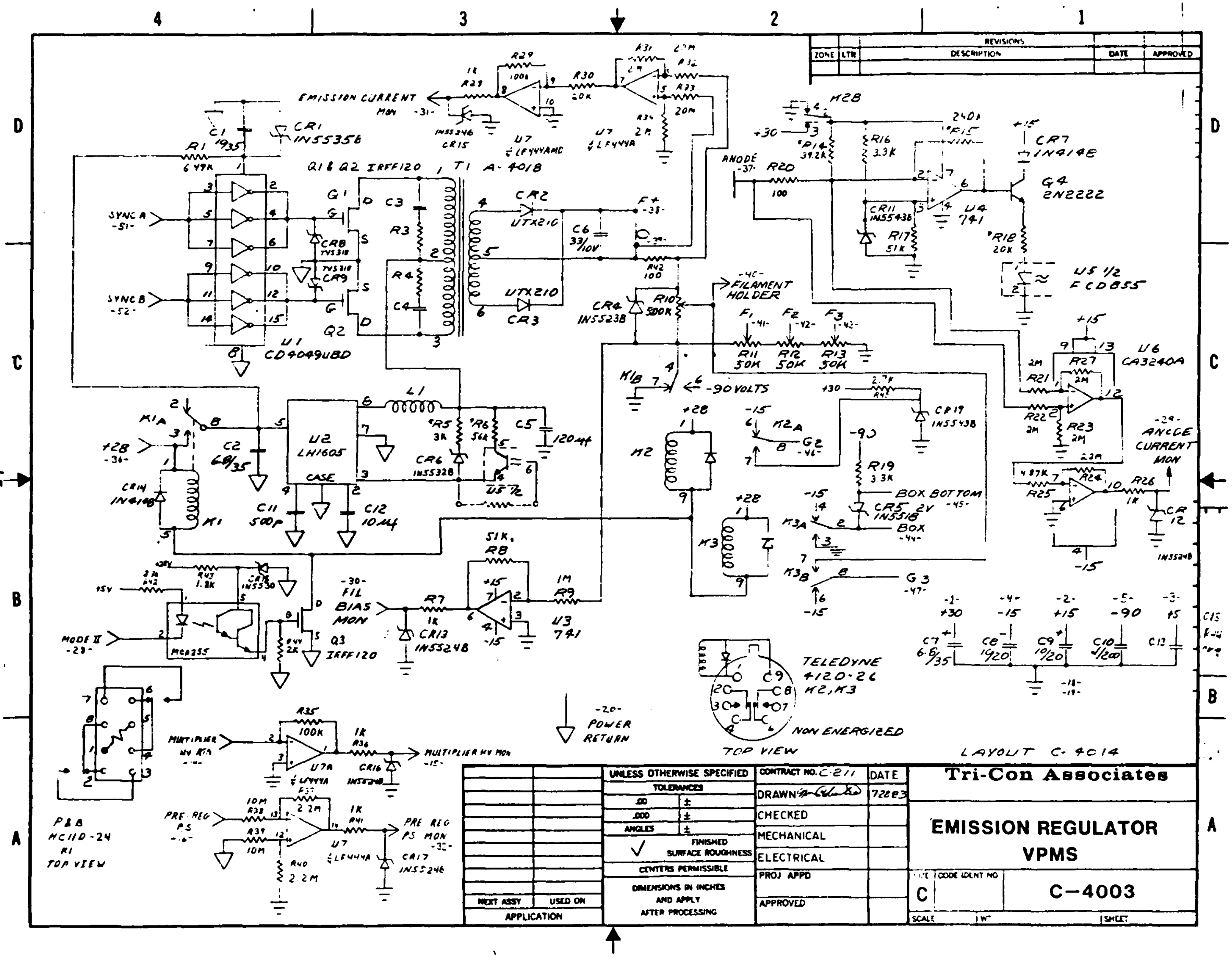

Tri-Con Associates
FLOATING CONVERTER
VPMS
C-3091
LAYOUT C-4011
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
FINISHED SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
NEXT ASSY
USED ON
APPLICATION
CONTRACT NO.
DATE
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
PROJ APPD
APPROVED
SIZE
C
CODE IDENT NO
SCALE
SHEET
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
UNITRODE TVS34E
TVS31B
IRF120
Q3
CR3
TVS 34B
Q4 LM117K
CASE
R5
R6
C6
R3 2.2K
C4
CR1
1N5535
MTP10N35
C2
CR2
CRB1
CRB2 673-1
TO M1-C
FROM GROUND REF CONVERTER
R1 9K
R2
C3
U1 CD4049UBD
C5 MTP156M060P1B
+40V
-40V
C14
CRB3 673-1
CRB4 673-1
CRB5 673-1
CRB6 673-1
R7 3W
7EM15HM
79M15HM
R8 3W
C7
C8
C9
C10
+15F
-15F
C11 33/10V
+5V
FR (FLOATING REFERENCE)
C12 .01
C13 .01
R9
R10
+100V
COMM Q
-100V
TO CRB1 +
M1 CR1
HL110-24
CR2
TO RF
FCD 855
CMD RET
SEE LAYOUT C-4013

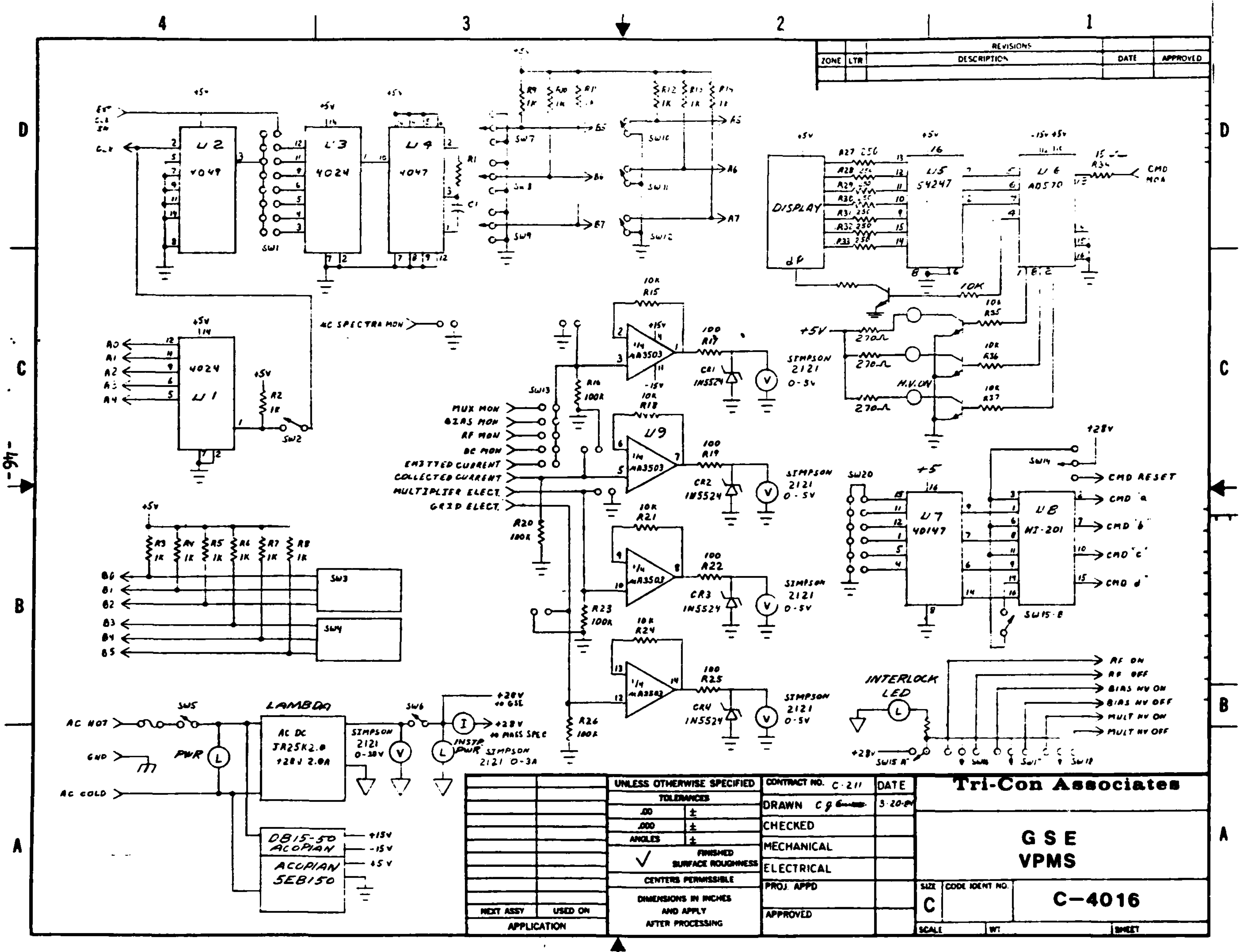

FROM SWEEP GENERATOR C-3093 -4-
TOTAL IONS C-3093
SWITCH IS ON WITH LOGIC ZERO
RETARD BIAS C-3093
DG200
RF CONT
COM Q
+DC
-DC
DC MON TO ISOLATION AMP U12-40 DWG C-3093
LM117HVH
LM137HVH
APERTURE ELECTROMETER (G5)
* RN55
LAYOUT C-4013
LAYOUT C-4011
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
FINISHED SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
NEXT ASSY
USED ON
APPLICATION
CONTRACT NO. C-211
DATE
DRAWN
4-22-83
CHECKED
MECHANICAL
ELECTRICAL
PROJ. APPD
APPROVED
Tri-Con Associates
SWEEP AND BIAS AMPLIFIERS VPMS
SIZE C
CODE IDENT NO.
C-3092
SCALE
WT
SHEET


Tri-Con Associates
DC SWEEP GENERATOR
VPMS
C-3093
CONTRACT NO. C-211
DATE 4-21-87
UNLESS OTHERWISE SPECIFIED
TOLERANCES
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
APPLICATION
NEXT ASSY
USED ON
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
PROJ APPD
APPROVED
SIZE C
SCALE
SHEET
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
U1 2730
U2 2730
U3 2730
U4 CA3130
U5 4040
U6 2KX8 CMOS MEMORY HM-6716 OR EQUAL
U7 AD7520
U8 AD581
U9 2KX8
U10 4049UB
U11 BB3510
U16 2730
Q1 2N2222
RESET
TO SWEEP AMPS C-3092
LAYOUT C-4013
TOP VIEW
SPARE P6-31
APER ELEC P6-27
DC MON P6-10
RF MON P6-29
TM BUFFER P7-25
INPUT FILTER
OUTPUT FILTER
END OF MASS SCAN P7-21
RF STATUS
PROGRAM TOTAL IONS



Tri-Con Associates
GROUND REFERENCE LOGIC VPMS
D-4002
HIGH VOLTAGE BIAS
MC6870SA3L
U3
PM2 D/A 2088X
HARRIS 5066
U13 5066
U17 BB3510
U15 BB3582
Q2 IRF120
U20 741
R32
R35
R37
U5 4024 7 BIT BIN
U6 405 MULTIPLEX
CD 4067
DIACOE
LM136-5
TC SHEEP
MEMORY
GPTC
ISOLATORS
TO U16-7 DWG C-3093
TO R2 DWG C-4063 MODE B SELECT
M6 SEE C 4063
POTTER & BRUMFIELD KL110-24 TOP VIEW
BLUE BEAD
ENERGIZED LAST
COIL A LAST ENERGIZED
LAYOUT C-4012


EMISSION CURRENT MON -31-
SYNC A -51-
SYNC B -52-
U1 CD4049UBD
Q1 & Q2 IRFF120
T1 A-4018
U2 LH1605
CASE
U7 ¼ LF444AHC
U7 ¼ LF444A
U4 741
G4 2N2222
U5 ½ FCD855
U6 CA3240A
ANODE -37-
F+ -38-
FILAMENT HOLDER -40-
-90 VOLTS
ANODE CURRENT MON -29-
BOX BOTTOM -45-
BOX -44-
FIL BIAS MON -30-
U3 741
Q3 IRFF120
MODE II -28-
POWER RETURN -20-
TELEDYNE 4120-26 K2,K3
NON ENERGIZED
TOP VIEW
LAYOUT C-4014
MULTIPLIER HV MON -15-
U7A ¼ LF444A
PRE REG PS MON -32-
P&B HC11D-24 K1 TOP VIEW
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
FINISHED SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
NEXT ASSY
USED ON
APPLICATION
CONTRACT NO. C-211
DATE
DRAWN
72283
CHECKED
MECHANICAL
ELECTRICAL
PROJ APPD
APPROVED
Tri-Con Associates
EMISSION REGULATOR
VPMS
CODE IDENT NO
C
C-4003
SCALE
SHEET
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED


Tri-Con Associates
GSE
VPMS
C-4016
UNLESS OTHERWISE SPECIFIED
TOLERANCES
CONTRACT NO. C-211
DATE
DRAWN
3-20-84
CHECKED
MECHANICAL
ELECTRICAL
PROJ. APPD
APPROVED
SIZE C
CODE IDENT NO.
SCALE
WT
SHEET
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
FINISHED SURFACE ROUGHNESS
NEXT ASSY
USED ON
APPLICATION
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
DISPLAY
LAMBDA
INTERLOCK LED
AC HOT
GND
AC COLD
PWR
AC SPECTRA MON
MUX MON
BIAS MON
RF MON
BC MON
EMITTED CURRENT
COLLECTED CURRENT
MULTIPLIER ELECT.
GRID ELECT.
CMD RESET
CMD 'a'
CMD 'b'
CMD 'c'
CMD 'd'
RF ON
RF OFF
BIAS HV ON
BIAS HV OFF
MULT HV ON
MULT HV OFF
SIMPSON 2121 0-5V
ACOPIAN 5EB150
DB15-50 ACOPIAN

```
                    title           'VPMS microcontroller program'
                    subtitle        'system equates, i/o'

0000        DATA_A  equ     000h    ; I/O data ports - port A
0001        DATA_B  equ     001h    ;                - port B
0002        DATA_C  equ     002h    ;                - port C
0003        DATA_D  equ     003h    ;                - port D

0004        DDR_A   equ     004h    ; Data direction registers - port A
0005        DDR_B   equ     005h    ;                          - port B
0006        DDR_C   equ     006h    ;                          - port C

0008        TDR     equ     008h    ; Timer data register
0009        TCR     equ     009h    ; Timer control register

000A        MR      equ     00Ah    ; Miscllaneous register

000B        PCR     equ     00Bh    ; Program control register
                                    ; *** DO NOT ALTER ***

000E        ACR     equ     00Eh    ; A/D control register
000F        ARR     equ     00Fh    ; A/D result register
```

```
                  subtitle             'system equate, ram'

0010        COUNT   equ     0010h      ; Storage for time delay loop
0011        SEGTEMP equ     0011h      ; Storage for segment select subroutine
0012        BIPS    equ     0012h      ; Vehicle potential
```

```
        subtitle        'Jump Table'
;************************************************************************
; Jump table
;
;       used to allow easy repositioning of the program modules.
;
;       Format:
;
;        jmp     MODULE_NAME            ; Jump to a sweep routine
;        db      ROM_SEGMENT_NUMBER     ; Rom segment to be used by routine
;                                       ; Uses 2 contiguous segments
;

        org     0080h           ; Must be the start of this table
JMPTB:
0080  C3 01 19          jmp     NOCMD           ; Command 0 - No command
0083  00                db      000h            ;   Rom segment 0 = idle state

0084  C3 04 00          jmp     MODE_I          ; Command 1 - Mode 1
0087  01                db      001h            ;   Segments 1, 2, 3, 4, 5, 6 (Only 3 are used)

0088  C3 04 02          jmp     MODE_IA         ; Command 2 - Mode 1A
008B  07                db      007h            ;   Segment 7, 8   (Only 1 is used)

008C  C3 01 19          jmp     NOTIMP          ; Command 3 - Not implemented
008F  00                db      000h            ;

0090  C3 05 00          jmp     MODE_II         ; Command 4 - Mode 2
0093  09                db      009h            ;   Segment 9, 10   (Only 1 is used)

0094  C3 01 19          jmp     NOTIMP          ; Command 5 - Not implemented
0097  00                db      000h            ;

0098  C3 01 19          jmp     NOTIMP          ; Command 6 - Not implemented
009B  00                db      000h            ;

009C  00 00 00          db      000h,000h,000h  ; Command 7 - HARDWARE RESET
009F  00                db      000h            ;
```

```
                        subtitle        'Initialization & Command monitor'
                ;***************************************************************************
                ; Initialization & Command Monitor
                ;
                ;       Executed upon hardware reset
                ;
                        org     0100h
                INIT:
0100  4F                clr     a
0101  B7 00             sta     $DATA_A         ; Initial data for output ports
0103  B7 01             sta     $DATA_B         ;
0105  B7 06             sta     $DDR_C          ; Now setup data direction and control reg's
0107  B7 0E             sta     $ACR            ;
0109  43                com     a               ;
010A  B7 04             sta     $DDR_A          ;
010C  B7 05             sta     $DDR_B          ;
010E  A6 07             lda     #007h           ;
0110  B7 0A             sta     $MR             ;
0112  A6 40             lda     #040h           ;
0114  B7 09             sta     $TCR            ;
0116  CC 01 19          jmp     $RDCMD          ;

                NOTIMP:
                RDCMD:
0119  B6 02             lda     $DATA_C         ; Get command
011B  CD 0E 30          jsr     WAIT100         ; debounce for relay's
011E  B1 02             cmp     $DATA_C         ; Q.  same command?
0120  26 F7             bne     RDCMD           ;    no, go back and read again
0122  48                lsl     a               ;
0123  48                lsl     a               ;
0124  AB 80             add     #JMPTB
0126  97                tax
0127  FD                jsr     [x]
0128  A6 00             lda     00h             ; Set to idle sweep
012A  CD 0E 00          jsr     SEGMENT         ;
012D  20 EA             bra     RDCMD           ; Reread command and execute indefinitely
```

```
        subttl          'Subroutines'
;*******************************************************************************
; Subroutines
;
;       SEGMENT:    -- Select desired rom segment
;               Entry:  x = jump table pointer used to enter sweep
;               Exit:   None
;               Uses:   a,flags
;
;       SWEEP:      -- Sweep quadrapole
;               Entry:  None
;               Exit:   None
;               Uses:   None
;
;       SWEEP_WR:  -- Sweep quadrapole with +2v retarding voltage
;               Entry:  None
;               Exit:   None
;               Uses:   None
;
;       WAIT100     -- 100 mSec. time delay
;               Entry:  None
;               Exit:   None
;               Uses:   a,flags,$0010h
;
;
```

```
                ;***********************************************************************
                ; SEGMENT
                ;
                        org     0200h
                SEGMENT:
0200  B7                sta     $SEGTEMP        ; Save segment number
0202  AA 20             ora     #020h           ; Set clock control bit to inhibit change
0204  B4 01             and     $DATA_B         ; Take present seg. # and clear neccesary bits
0206  BA 11             ora     $SEGTEMP        ;   then set neccesary bits
0208  B7 01             sta     $DATA_B         ; Store the new segment address
020A  81                rts                     ;


                ;***********************************************************************
                ; SWEEP_WR  &  SWEEP
                ;
                        org     0210h
                SWEEP_WR:
0210  18 01             bset    4,$DATA_B       ; Apply retarding voltage
                SWEEP:
                ;   We must be sure a full sweep has occured
                ;   If EDMS is high
                ;       Then wait for it to go low then high
                ;   If EDMS is low
                ;       Then wait for it to go high then low
                ;
0212  0E 02 0D          brset   7,$DATA_C,SET2  ; Branch if EDMS is high
                ;
                ;
                ;       To get here, EDMS must be low.
                ;
0215  0F 02 FD  CLR1:   brclr   7,$DATA_C,CLR1  ; Wait for EDMS to go high
0218  0E 02 FD  SET1:   brset   7,$DATA_C,SET1  ; Wait for EDMS to go low
021B  20 06             bra     CONT            ; Continue
                ;
                ;
                ;       To get here, EDMS must be high.
                ;
021D  0E 02 FD  SET2:   brset   7,$DATA_C,SET2  ; Wait for EDMS to go low
0220  0F 02 FD  CLR2:   brclr   7,$DATA_C,CLR2  ; Wait for EDMS to go high

                ; Continue with sweep subroutine
                ;
                CONT:
0223  19 01             bclr    4,$DATA_B       ; Disable +2v retarding voltage
0225  81                rts                     ;  (Doesn't matter if it was turned on or not)
```

```
                        [illegible]   [illegible]
                        ;*************************************************************************
                        ; WAIT100
                        ;               Delay = [illegible] 1000 * VAL [illegible] uSec.
                        ;               VAL = [illegible] Delay [illegible] uSec. [illegible] 1000
                        ;
0064                    VAL     equ     $64             ; 100 decimal for a [illegible] Sec. delay
                                                        ;   real delay is [illegible] uSec.
                        WAIT100:
0230  B6 64                     lda     VAL             ; 2 ; Compute delay from above formula
0232  B7 [illegible]            sta     $COUNT          ; 4 ;
                        WAIT1:
0234  A6 [illegible]            lda     #[illegible]    ; 2 ; set inner timing loop to [illegible] uSec.
                        WAIT2:
0236  4A                        dec     a               ; 3 ;   Inner timing loop
0237  26 FD                     bne     WAIT2           ; 3 ;

0239  3A [illegible]            dec     $COUNT          ; 5 ;   Outer timing loop
023B  26 F7                     bne     WAIT1           ; 3 ;
023D  81                        rts                     ; 6 ;
```

```
                  subtitle        'Mode 1 sweep module'
                ;**************************************************************************
                ; Mode 1  sweep module
                ;
                ;       Entry:  x = jump table pointer used to get here
                ;       Exit:   None
                ;       Uses:   a,flags
                ;

0085            THRESHOLD equ   085h            ; Minimum reading to determine vehicle potential
                                                ;  (this is just a dummy value)
                        org     0400h
                MODE_1:
0400  E6 03             lda     3,x             ; Get segment # out of table
0402  CD 02 00          jsr     SEGMENT         ; Select rom segment
                AD_RESET:
0405  4F                clr     a               ; Reset A/D
0406  B7 0E             sta     $ACR            ;
                AD_STATUS:
0408  B6 0E             lda     $ACR            ;
040A  2A FC             bpl     AD_STATUS       ; Br if the A/D conversion is not complete
040C  B6 0F             lda     $ARR            ; Read A/D
040E  A1 85             cmp     #THRESHOLD      ;
0410  23 09             bls     BIAS_FOUND      ; Br if reading has fallen to threshold
0412  B6 00             lda     $DATA_A         ;    else, increase HV bias and take another
0414  4C                inc     a               ;    sample
0415  A4 7F             and     07Fh            ; We must make sure we don't turn on mode 2
0417  B7 00             sta     $DATA_A         ;
0419  20 EA             bra     AD_RESET        ;

                BIAS_FOUND:
041B  B6 00             lda     $DATA_A         ; Get value of HV bias
                ;               Adjust HV Bias if neccisary
041D  B7 00             sta     $DATA_A         ; Set adjusted HV bias
041F  B7 ..             sta     $DLAS           ; Save for more elaborate routines
0421  3C 01             inc     $DATA_B         ; Set rcm segment for next sweep type
0423  CD 02 ..          jsr     SWEEP           ; Sweep quadrapole
0426  CD 0. ..          jsr     SWEEP_WR        ; Sweep quad w/ +2v retard
0429  3C 01             inc     $DATA_B         ; Set rom segment for next sweep type
042B  CD 0. ..          jsr     SWEEP           ; Sweep quad
042E  CD 0. 10          jsr     SWEEP_WR        ; Sweep quad w/ +2v retard
0431  81                rts
```

```
                  subtitle       'Mode 1A sweep module'
              ;***************************************************************************
              ; Mode 1A sweep module
              ;
              ;       Entry:  x = jump table pointer used to get here
              ;       Exit:   None
              ;       Uses:   a,flags
              ;

                      org     0480h
              MODE_1A:
0480  E6 03           lda     [x],3           ; Get segment # from table
0483  CD 02 00        jsr     SEGMENT         ; Select row segment
0486  CD 02 12        jsr     SWEEP           ; Sweep quadrapole
0489  CD 02 10        jsr     SWEEP_WR        ; Sweep quad w/ +2v retard
048C  81              rts                     ;
```

```
                    subtitle        'Mode 2 sweep module'
                ;*******************************************************************************
                ; Mode 2 sweep module
                ;
                ;       Entry:  x = jump table pointer used to get here
                ;       Exit:   None
                ;       Uses:   a,flags
                ;

                        org     0580h
                MODE_II:
0580  E6 03             lda     [x],3           ; Get segment # from table
0582  CD 02 00          jsr     SEGMENT         ; Select rom segment
0585  18 00             bset    7,$DATA_A       ; Set up mode 2
0588  CD 0C 12          jsr     SWEEP           ; Sweep quadrapole
058B  CD 02 10          jsr     SWEEP_WR        ; Sweep quad w/ +2v retard
058E  81                rts                     ;
```

```
                        subtitle        'Interupt service'
                ;*******************************************************************************
                ; Interupt service routines
                ;
                ;       This is a dummy routine just in case a stray interupt occurs
                ;

                        org     0F30h
                INT_SERVICE:
0F30  80                rti                     ; Safety precaution


                        subtitle        'Interupt vectors'
                ;*******************************************************************************
                ; Interupt vectors
                ;
                ;
                ;

                        org     0FF8h
                INT_VECTORS:
0FF8  0F 30             dw      INT_SERVICE     ; Timer or INT2 (external)
0FFA  0F 30             dw      INT_SERVICE     ; INT (external)
0FFC  0F 30             dw      INT_SERVICE     ; SWI
0FFE  01 00             dw      INIT            ; HARDWARE RESET

                        end
```

END

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DTIC